SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Technical Note No. 76 (14) TN-76
2. GOVT ACCESSION NO
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): (6) TELNET under Single-Connection TCP Specification
5. TYPE OF REPORT & PERIOD COVERED: (7) Technical Note
6. PERFORMING ORG. REPORT NUMBER: -

7. AUTHOR(s): (10) Darryl E./Rubin
8. CONTRACT OR GRANT NUMBER(s): (15) MDA903-76C-0093, ARPA Order No.-2494

9. PERFORMING ORGANIZATION NAME AND ADDRESS: (11) 2 Feb 76
Stanford Electronics Laboratories
Stanford University
Stanford, CA 94305 (12) 17 p.
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 6T10

11. CONTROLLING OFFICE NAME AND ADDRESS
Defense Advanced Research Projects Agency
Information Processing Techniques Office
1400 Wilson Ave., Arlington, VA 22209
12. REPORT DATE: Feb. 2, 1976
13. NO. OF PAGES: 20

14. MONITORING AGENCY NAME & ADDRESS (if diff. from Controlling Office)
Mr. Philip Surra, Resident Representative
Office of Naval Research, Durand 165
Stanford University, Stanford, CA 94305
15. SECURITY CLASS. (of this report): UNCLASSIFIED
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this report)
Reporduction in whole or in part is permitted for any purpose of the U. S. Government
"A"

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

DDC RECEIVED MAY 26 1976 B

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Interconnection, communication protocols, TELNET, ARPANET, Packet Radio Network

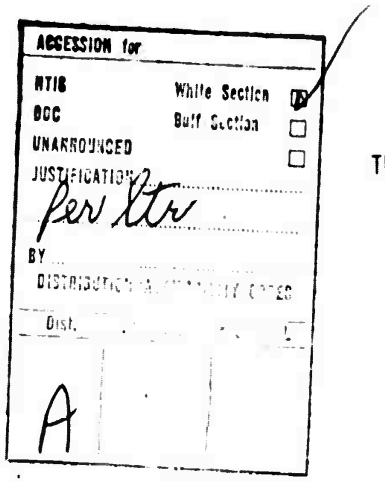
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
The necessary functions of a user-TELNET to run under TCPØ on a microprocessor (as in a mobile packet radio terminal) are described. A detailed implementation specification for the mini-TELNET is presented in an ALGOL-like notation, along with a discussion of its user interface, and control and data structures.

DD FORM 1 JAN 73 1473
EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

408 071

AD A024821



TELNET under Single-Connection TCP Specification

D. E. Rubin

Digital Systems Laboratory
Stanford University
Stanford, California 94305

February 2, 1976

Technical Note #76

DIGITAL SYSTEMS LABORATORY
Dept. of Electrical Engineering Dept. of Computer Science
Stanford University
Stanford, California

This research was supported by the Defense Advanced Research Projects Agency under ARPA Order No. 2494, Contract No. MDA903-76C-0093.

Table of Contents

1 Introduction

One of the goals of the evolving Packet Radio Network (PRNET) is to provide for network access through portable packet radio terminals. These terminals will implement packet radio software on a DEC LSI-11, INTEL 8080, or similar microprocessor. Owing to the unnecessary complexity and generality of the Transmission Control Protocol [1] used by the PRNET, a single connection subset (TCP0) has been designed specifically for portable PRNET terminal application [2].

Given a user TCP0, it is necessary to provide a means of interfacing a user at the portable interactive terminal to the TCP0 and thereby to the net to which he is attached. This interface should provide for establishment and control of network connections, and interactive data flow between the net and the user, as well as specification by the user of various echoing and command intercept options. In the Arpanet, these functions are provided by the TELNET protocol [3]. This paper provides an implementation specification for a TELNET to run under TCP0 without operating system support on a microprocessor. Design objectives were therefore small size, simplicity, and a structure appropriate for character at a time data streams at or slower than 120 cps. It is assumed that the reader is familiar with the TCP0 user interface [2], the TELNET protocol [3], and the Arpanet TIP user interface [4].

2 The User TELNET

All interactive traffic flow between the terminal and the network is mediated by the TELNET, which also performs user command interpretation and execution, presenting a subset of the standard Arpanet TIP user interface. Commands include:

1) "@o <NET>,<TCP>,<SOCKET>": opens the full duplex connection specified by the supplied foreign net, tcp and socket numbers, and the implied local socket.

2) "@c": closes the network connection.

3) "@t c": sets transmit character at a time mode.

4) "@t l": sets transmit line at a time mode.

5) "@e l": sets local echo mode.

6) "@e r": sets remote echo mode.

7) "@l <character code>": sets a new command intercept character.

The TELNET consists of a single, non-reentrant, non-preemptable process, composed of a set of service routines and a single cyclic wait (polling) routine, from which the service procedures are dispatched on event completion. (Note that execution of the wait causes a context switch to the next in a circular queue of processes: TELNET, TCP0 SEND, TCP0 RECEIVE). Events include:

1) Change in connection or command handling status (e.g., connection opened, or bad command syntax).

2) Reception of new data over the network connection.

3) Reception of a new character from the terminal.

4) TCP0 send completion.

5) Terminal output completion.

An event scoreboard composed of logical flags is used to signal these events and control dispatch of the appropriate service routines. The flags corresponding to 1 through 5 above are:

1) STATUS flags: these control dispatch of the procedure COMPOSEMESSAGE. They include OPEN (connection opened), ERROR (connection error), CLOSED (connection closed), HOSTNR (host not responding), CANT (command cannot be serviced), and BAD (bad command syntax). Any of these but BAD can be set to TRUE by TCP0.

2) NEWDATA: dispatches either PROCESSDATA or PROCESSTELNETCMD, dependent upon whether the current input is a TELNET escape sequence. This flag is set to TRUE by TCP0 when new data awaits delivery to the user process.

3) TTYINPUT: dispatches either PROCESSCHAR or PROCESSCOMMAND dependent upon whether the current input is a user command intercept sequence. It is set to TRUE by the TTY input interrupt service routine.

4) SENDREADY: dispatches AWAKENSEND. This flag is set to TRUE by TCP0 when new data can be accepted for sending to the net.

5) PRINTERIDLE: dispatches AWAKENPRINTER. It is set to TRUE by the TTY output interrupt service routine.

Note that other conditions can inhibit the dispatch of any of the above service routines. In general, test conditions in the wait routine permit a routine call only if the routine can run to completion

at that time, without the need for an intermediate event wait. For example, PROCESSDATA will not be called while there is no buffer space for the new character, even though NEWDATA signals data reception. For the one volatile event, TTYINPUT, a special flag, RINGBELL, is set should neither service routine be immediately dispatchable. This causes the terminal output driver to warn the user with a CONTROL-G (bell) that input is being rejected.

3 Data Structures

The data structures used by the TELNET are eight buffers:

TELNETMSGBUF[j]: two linear buffers (j=0 or 1) in which TELNET option negotiation messages destined for the net are placed for double buffered output. Associated with these buffers is a flag, TELNETCMDREADY, which indicates that the current buffer (TELNETMSGBUF[j]) contains an unsent TELNET command. This flag inhibits dispatch of PROCESSTELNETCMD and execution of the user command "E" (echo mode) until its value is FALSE.

SENDBUF[i]: two linear buffers (i=0 or 1) in which the output stream of user data to the net is queued for double buffered output. Associated with these buffers is three variables: a). XMITMODE (= "C" or "L")--indicates whether character- or line-at-a-time transmission is in effect, b). CHARSTOSEND--a flag that indicates to the procedure AWAKENSEND when it is time to SEND the contents of SENDBUF[i] to the net, c). BYTECOUNT--this counter is passed to the TCP0 in a SEND call and specifies the number of octets to be sent. Service routine dispatch for the TTYINPUT event is inhibited while SENDBUF[i] is full.

MESSAGEBUF: a linear buffer used for construction of user status messages destined for the terminal. Dispatch of COMPOSEMESSAGE is inhibited while this buffer is non-empty.

ECHOBUF: a circular queue containing the stream of characters to be locally echoed. All characters of a command intercept sequence are automatically enqueued here. Associated with this buffer is a variable ECHOMODE (= "R" for remote, "L" for local) which indicates whether locally generated characters are to be echoed.

RECEIVEBUF: a circular queue in which characters received over the network connection are placed. Dispatch of NEWDATA

event service procedures is inhibited while RECEIVEBUF is full.

COMMANDBUF: a linear queue for assembly of user commands. If it is overflowed, the user is informed with a "BAD" status message.

Note that there are two output streams to the network (TELNETMSGBUF[j] and SENDBUF[i]) and three output streams to the terminal (MESSAGEBUF, ECHOBUF, RECEIVEBUF). This scheme greatly simplifies buffer management and the overall control structure, as well as permitting a priority structure to be assigned to different characters, depending upon source (the streams are listed above from highest to lowest priority); characters of higher priority are processed for output before those lower in the hierarchy.

Also an important part of the control/data structure are two counting variables:

TELNETCOUNT: indicates how many bytes of a TELNET escape sequence have been received over the network connection (the start of such a sequence is signalled by an "IAC" in the TELNET input stream). On NEWDATA event it is used to select between PROCESSDATA (if=0) and PROCESSTELNETCMD (if>0).

COMMANDCOUNT: indicates how many bytes of a command intercept sequence have been received from the terminal (the start of such a sequence is signalled by an INTERCEPTCHAR in the terminal input stream). On TTYINPUT event, it is used to select between PROCESSCHAR (if=0) and PROCESSCOMMAND (if>0).

4 Service Routines

There are four categories of TELNET service procedures:

1) Net input handlers: PROCESSDATA, PROCESSTELNETCMD.

2) Terminal input handlers: PROCESSCHAR, PROCESSCOMMAND, PARSE, ASCIITOBINARY.

3) Net output handlers: AWAKENSEND, TELNETREPLY, SENDCHAR.

4) Terminal output handlers: TTYINPUTINTERRUPTSERVICE, TTYOUTPUTINTERRUPTSERVICE, COMPOSEMESSAGE, AWAKENPRINTER, TYPENEXT, TYPE.

Each list of routines is in top level to lower level order.

COMPOSEMESSAGE is called from the event wait loop when MESSAGEBUF is free and a STATUS flag has been set. For each set flag, status text is placed in MESSAGEBUF. All status flags are then reset to FALSE.

PROCESSDATA is called from the wait loop if a terminal-bound character arrives and RECEIVEBUF has space. The character is fetched from the TCP0 via a RECEIVE call, and then enqueued in RECEIVEBUF, unless it is "IAC", in which case TELNETCOUNT is incremented.

PROCESSTELNETCMD is called from the wait loop when a TELNET command byte arrives. It has two entry points, one chosen by the value of TELNETCOUNT. The first handles reception of the second byte of the escape sequence. If this byte is "IAC", then it is enqueued in RECEIVEBUF and TELNETCOUNT reset to zero, else it is saved in the variable COMMAND and TELNETCOUNT incremented. The second entry point handles reception of the third byte (stored into OPTION) and acts on the TELNET command received by sending out an appropriate TELNET reply, plus possibly setting a new ECHOMODE value.

TELNETREPLY is called from PROCESSTELNETCMD, and passed either "DONT" or "WONT". It assembles a TELNET reply in TELNETMSGBUF[j], using this parameter and OPTION, and sets TELNETCMDREADY to TRUE.

PROCESSCHAR is called from the wait loop when a new net-destined character arrives from the terminal and there is buffer room for it. If the new character is the command intercept character, INTERCEPTCHAR, then conditions are initialized for command collection, otherwise the character is prepared for transport to the net by a call on SENDCHAR.

PROCESSCOMMAND is called from the wait loop when a user command byte arrives from the terminal. The character is enqueued in ECHOBUF and COMMANDBUF. If a carriage return, PARSE is called.

SENDCHAR is called from PROCESSCHAR and PROCESSCOMMAND. The character, passed in the global variable CHAR, is enqueued in SENDBUF[i], and if local echo is set, it is also enqueued in ECHOBUF. If the character is special (e.g., a control character, carriage return, or escape), if the transmission mode is character at a time, or if SENDBUF[i] is full, CHARSTOSEND is set to TRUE, signalling that a SEND should be issued.

PARSE is called when COMMANDBUF contains a complete command. Syntax is checked; if not good, BAD is set to TRUE. Otherwise, the appropriate action is taken (e.g., issuing an OPEN, CLOSE, setting a new intercept character, etc.).

ASCIITOBINARY is called from PARSE, and converts an ASCII string in radix-10 to binary, of length in bits specified by a parameter. This

routine uses a global index into COMMANDBUF, STRINGORIGIN, to find the left end of the string. A global flag, BADSTRING, is set to TRUE if bad string syntax. STRINGORIGIN is returned pointing to the character past the string delimiter (CR or COMMA if good syntax).

AWAKENSEND is dispatched from the event wait loop on signal from the TCP0 via SENDREADY. If there is a TELNET reply ready, it is sent via a SEND call. Otherwise, if CHARSTOSEND, then SENDBUF[i] is output via a SEND. In either case, buffer switching is performed after the SEND.

TTYINPUTINTERRUPTSERVICE and TTYOUTPUTINTERRUPTSERVICE are called via device interrupt. They set to TRUE the TTYINPUT and PRINTERIDLE flags respectively.

AWAKENPRINTER is called from the event wait loop when PRINTERIDLE. From highest to lowest priority it will do one of:

1) TYPE a CONTROL-G if RINGBELL is TRUE, and set RINGBELL to FALSE.

2) TYPE the next character of a carriage return expansion (if CRCOUNT>0). A variable, NULLSNEEDED, controls the number of null characters generated in the expansion.

3) TYPE the next space of a tab expansion (if TABCOUNT>0).

4) TYPENEXT the contents of MESSAGEBUF, if non-empty.

5) TYPENEXT the contents of ECHOBUF, and set TABCOUNT or CRCOUNT to the appropriate value if the character is a tab or carriage return.

6) TYPENEXT the contents of RECEIVEBUF.

TYPENEXT is passed a buffer, from which it dequeues the next character and then TYPEs it. A variable COLCOUNT is also maintained. This is used in setting TABCOUNT for tab expansion.

TYPE is passed a character which it sends to the terminal for printing. PRINTERIDLE is set to FALSE.

5 Pseudo-Algol Implementation Guide

```
begin

TELNETINIT:

(initialize all buffers);
TELNETCOUNT←COMMANDCOUNT←0;
TABCOUNT←CRCOUNT←0;
BYTECOUNT←COLCOUNT←0;
i←j←0;
NULLSNEEDED←(whatever is appropriate for the device);
ECHOMODE←REQUESTEDMODE←"R";
XMITMODE←"C";
INTERCEPTCHAR←"@";
(all flags but PRINTERIDLE set to FALSE);
PRINTERIDLE←TRUE;
(whatever other minor housekeeping details);

WAITLOOP:

(wait for signal);

if (OPEN|ERROR|CLOSED|CANT|BAD|HOSTNR) and (MESSAGEBUF empty) then
    COMPOSEMESSAGE;

if NEWDATA and (RECEIVEBUF not full) then

    if (TELNETCOUNT=0) then
        begin
        NEWDATA←FALSE;
        PROCESSDATA;
        end

    else if (not TELNETCMDREADY) then
        begin
        NEWDATA←FALSE;
        PROCESSTELNETCMD;
        end;

if TTYINPUT then

    begin
    if (SENDBUF[i] full) or (ECHOBUF full) then RINGBELL←TRUE else
        if COMMANDCOUNT=0 then PROCESSCHAR else PROCESSCOMMAND;
    TTYINPUT←FALSE;
    end;

if SENDREADY then AWAKENSEND;
```

```
if PRINTERIDLE then AWAKENPRINTER;

go to WAITLOOP;

PROCEDURE COMPOSEMESSAGE;

    begin
    if BAD then (place "BAD<CRLF><NULL STRING>" in MESSAGEBUF);
    if CANT then (place "CANT<CRLF><NULL STRING>" in MESSAGEBUF);
    if OPEN then (place "OPEN<CRLF><NULL STRING>" in MESSAGEBUF);
    if ERROR then (place "CONNECTION ERROR . . . etc);
    if HOSTNR then (place "HOST NOT RESPONDING . . . etc);
    if CLOSED then (place "CLOSED . . . etc);
    BAD←CANT←OPEN←ERROR←HOSTNR←CLOSED←FALSE;
    end;

PROCEDURE PROCESSDATA;

    begin
    RECEIVE(CHAR,1,BYTESXFERRED);
    if CHAR=IAC then TELNETCOUNT←1 else (enqueue CHAR in RECEIVEBUF);
    end;

PROCEDURE PROCESSTELNETCMD;

    case TELNETCOUNT of

        =1:
        begin
        RECEIVE(COMMAND,1,BYTESXFERRED);

        if COMMAND not equal (WILL|WONT|DO|DONT) then
            begin
            TELNETCOUNT←0;
            if COMMAND=IAC then (place "IAC" in RECEIVEBUF);
            end
        else TELNETCOUNT←2;

        end;

        =2:
        begin
        TELNETCOUNT←0;
        RECEIVE(OPTION,1,BYTESXFERRED);

        case COMMAND of

            =WILL:
            if (OPTION=ECHO) and (REQUESTEDMODE="R") then
                ECHOMODE←"R"
            else TELNETREPLY(DONT);
```

```
            =DO:
            TELNETREPLY(WONT);

            =WONT:
            if (OPTION=ECHO) then
                if REQUESTEDMODE="R" then CANT←TRUE else
                        ECHOMODE←"L";

            =DONT:
            TELNETREPLY(WONT);

        end;

PROCEDURE TELNETREPLY(CMD);

    begin
    (place "<IAC><CMD><OPTION>" into TELNETMSGBUF(j));
    TELNETCMDREADY←TRUE;
    end;

PROCEDURE PROCESSCHAR;

    begin
    (fetch tty character to CHAR);

    if CHAR=INTERCEPTCHAR then
        begin
        COMMANDCOUNT←1;
        (initialize COMMANDBUF);
        (enqueue CHAR in ECHOBUF);
        end
    else SENDCHAR;

    end;

PROCEDURE SENDCHAR;

    begin
    if (ECHOMODE="L") then (enqueue CHAR in ECHOBUF);
    (enqueue CHAR in SENDBUF[i]);
    BYTECOUNT←BYTECOUNT+1;
    if (CHAR a special character) or (XMITMODE="C") or (SENDBUF[i] full)
        then CHARSTOSEND←TRUE;
    end;

PROCEDURE PROCESSCOMMAND;

    begin
    (fetch tty character to CHAR);
    (fold CHAR to upper case);

    if COMMANDCOUNT=1 and CHAR=INTERCEPTCHAR then
```

```
        begin
        COMMANDCOUNT←0;
        SENDCHAR;
        end

    else    begin
        (enqueue CHAR in ECHOBUF);

        if (COMMANDBUF not full) then
            begin
            (enqueue CHAR in COMMANDBUF);
            COMMANDCOUNT←COMMANDCOUNT+1;
            if CHAR=CR then PARSE;
            end

        else    begin
            BAD←TRUE;
            COMMANDCOUNT←0;
            end;

        end;

    end;

PROCEDURE PARSE;

    if COMMANDBUF(2) not equal (SPACE|CR) then BAD←TRUE else

        begin
        case COMMANDBUF(1) of

            =C:
            if COMMANDBUF(2)=CR then CLOSE else BAD←TRUE;

            =O:
            begin
            BADSTRING←FALSE;
            STRINGORIGIN←3;
            NET←ASCIITOBINARY(8);
            TCP←ASCIITOBINARY(16);
            SOCKET←ASCIITOBINARY(24);

            if BADSTRING or COMMANDBUF(STRINGORIGIN-1) not = CR then
                BAD←TRUE

                else    begin
                OPEN(NET,TCP,SOCKET,RETURNCODE);
                if RETURNCODE not equal 0 then CANT←TRUE;
                end;

            end;
```

```
                =I:
                begin
                BADSTRING←FALSE;
                STRINGORIGIN←3;
                TEMP←ASCIITOBINARY(7);

                if BADSTRING or COMMANDBUF(STRINGORIGIN-1) not =CR then
                    BAD←TRUE
                else INTERCEPTCHAR←TEMP;

                end;

                =T:
                if COMMANDBUF(4)=CR and COMMANDBUF(3)=("C"|"L") then
                    XMITMODE←COMMANDBUF(3)
                else BAD←TRUE;

                =E:
                begin
                if COMMANDBUF(4)=CR and COMMANDBUF(3)=("L"|"R") then
                    if ECHOMODE not equal COMMANDBUF(3) then
                        if TELNETCMDREADY then BAD←TRUE else

                            begin
                            REQUESTEDMODE←COMMANDBUF(3)
                            if REQUESTEDMODE="L" then
                                (set <IAC><DONT><ECHO>
                                in TELNETMSGBUF[j])
                            else (set <IAC><DO><ECHO>
                                in TELNETMSGBUF[j]);
                            TELNETCMDREADY←TRUE;
                            end

                else BAD←TRUE;
                end;

                =(anything else):
                BAD←TRUE;

            COMMANDCOUNT←0;
            end;

    BINARY PROCEDURE ASCIITOBINARY(LENGTH);

        begin
        (convert string from left to right starting at
        STRINGORIGIN in COMMANDBUF to binary, and stop when a
        delimiter is found or "LENGTH" bits is overflowed);

        if (LENGTH is overflowed) or (delimiter not equal (cr|",")) then
            BADSTRING←TRUE;
```

```
    (leave STRINGORIGIN pointing to character after delimiter);
    end;

PROCEDURE AWAKENSEND;

    if TELNETCMDREADY then

        begin
        TELNETCMDREADY←SENDREADY←FALSE;
        SEND(TELNETMSGBUF[j],3);
        j←(j+1) mod 2;
        end

    else if CHARSTOSEND then

        begin
        CHARSTOSEND←SENDREADY←FALSE;
        SEND(SENDBUF[i],BYTECOUNT);
        BYTECOUNT←0;
        i←(i+1) mod 2;
        end;

PROCEDURE AWAKENPRINTER;

    if RINGBELL then

        begin
        RINGBELL←FALSE;
        TYPE(CONTROLG);
        end

    else if CRCOUNT>0 then

        begin
        CRCOUNT←CRCOUNT+1;
        if CRCOUNT=2 then TYPE(LF) else
            begin
            TYPE(NULL);
            if CRCOUNT=NULLSNEEDED+2 then CRCOUNT←0;
            end
        end

    else if TABCOUNT>0 then

        begin
        TYPE(SPACE);
        TABCOUNT←TABCOUNT-1;
        end

    else if (MESSAGEBUF not empty) then TYPENEXT(MESSAGEBUF)

    else if (ECHOBUF not empty) then
```

```
        begin
        if (next character is TAB) then TABCOUNT←(8-COLCOUNT) else
            if (next character is a CR) then CRCOUNT←1;
        TYPENEXT(ECHOBUF);
        end

    else if (RECEIVEBUF not empty) then TYPENEXT(RECEIVEBUF);

PROCEDURE TYPENEXT(BUFFER);

    begin
    (dequeue next character from BUFFER into CHAR);
    if (CHAR is printable) then COLCOUNT←(COLCOUNT+1) MOD 8 else
        if CHAR=CR then COLCOUNT←0;
    TYPE(CHAR);
    end;

PROCEDURE TYPE(CHARACTER);

    begin
    PRINTERIDLE←FALSE;
    (send CHARACTER to tty);
    end;

PROCEDURE TTYINPUTINTERRUPTSERVICE;

    begin
    (service the device);
    NEWDATA←TRUE;
    end;

PROCEDURE TTYOUTPUTINTERRUPTSERVICE;

    begin
    (service the device);
    PRINTERIDLE←TRUE;
    end;

end.
```

References

1. V. Cerf, Y. Dalal, C. Sunshine, "Specification of Internet Transmission Control Program," INWG Note 72, December 1974 (Revised).

2. J. E. Mathis, "Single-Connection TCP Specification (Preliminary Documentation)," Stanford University Digital Systems Laboratory Technical Note No. 75, January 1976.

3. A. McKenzie, "TELNET Protocol Specification," NIC No. 18639, August 1973.

4. J. Malman, "Arpa Terminal Interface Message Processor User's Guide," NIC No. 10916, August 1975.

DISTRIBUTION

ARPA

Director (2 copies)
ATTN: Program Management
Advanced Research Projects Agency
1400 Wilson Boulevard
Arlington, VA 22209

ARPA/IPT
1400 Wilson Boulevard
Arlington, VA 22209

Dr. Robert Kahn
Mr. Steven Walker

Bell Laboratories

Dr. Elliot N. Pinson, Head
Computer Systems Research Dept.
Bell Laboratories
600 Mountain Avenue
Murray Hill, New Jersey 07974

Dr. Samuel P. Morgan, Director
Computing Science Research
Bell Laboratories
610 Mountain Avenue
Murray Hill, New Jersey 07974

Dr. C. S. Roberts, Head
The Interactive Computer Systems
Research Department
Bell Laboratories
Holmdel, New Jersey 07733

Bolt Beranek and Newman Inc.
50 Moulton Street
Cambridge, Massachusetts 02138

Mr. Jerry D. Burchfiel
Mr. R. Clements
Mr. A. McKenzie
Mr. J. McQuillan
Mr. R. Tomlinson
Mr. D. Walden

Burroughs Corporation

Dr. Wayne T. Wilner, Manager
Burroughs Corporation
3978 Sorrento Valley Boulevard
San Diego, CA 92121

Mr. David H. Dahm
Burroughs Corporation
Burroughs Place
P. O. Box 418
Detroit, MI 48232

Mr. B. A. Creech, Manager
New Product Development
Burroughs Corporation
460 Sierra Madre Villa
Pasadena, CA 91109

Cabledata Associates

Mr. Paul Baran
Cabledata Associates, Inc.
701 Welch Road
Palo Alto, CA 94304

California, University - Irvine

Prof. David J. Farber
University of California
Irvine, CA 92664

California, University - Los Angeles

Professor Gerald Estrin
Computer Sciences Department
School of Engineering and Applied Science
Los Angeles, CA 90024

Professor Leonard Kleinrock
University of California
3732 Boelter Hall
Los Angeles, CA 90024

Mr. William E. Naylor
University of California
3804-D Boelter Hall
Los Angeles, CA 90024

Collins Radio Group
1200 N. Alma Road
Richardson, Texas 75080

Mr. Don Heaton
Mr. Frederic Weigl

Defense Communications Engineering Center

Dr. Harry Helm
DCEC, R-520
1860 Wiehle Avenue
Reston, VA 222090

General Electric

Dr. Richard L. Shuey
General Electric Research and Development Center
P. O. Box 8
Schenectady, New York 12301

Dr. A. Bell Isle
General Electric Company
Electronics Laboratory
Electronics Park
Syracuse, New York 13201

Mr. Ronald S. Taylor
General Electric Company
175 Curtner Avenue
San Jose, CA 95125

General Motors Corporation
Computer Science Department
General Motors Research Laboratories
General Motors Technical Center
Warren, MI 48090

Dr. George C. Dodd, Assistant Head
Mr. Fred Krull, Supervisory Research Engineer
Mr. John Boyse, Associate Senior Research Engineer

Hawaii, University of
The ALOHA System
2540 Dole Street, Holmes 486
Honolulu, Hawaii 96822

Professor Norman Abramson

Hughes Aircraft Company

Mr. Knut S. Kongelbeck, Staff Engr.
Hughes Aircraft Company
8430 Fallbrook Avenue
Canoga Park, CA 91304

Mr. Allan J. Stone
Hughes Aircraft Corporation
Bldg. 150 M.S. A 222
P. O. Box 90515
Los Angeles, CA 90009

Hughes Aircraft Company
Attn: B. W. Campbell 6/E110
Company Technical Document Center
Centinela and Teale Streets
Culver City, CA 90230

IBM

Dr. Patrick Mantey, Manager
User Oriented Systems
International Business Machines Corp.
K54-282, Monterey and Cottle Roads
San Jose, CA 95193

Dr. Leonard Y. Liu, Manager
Computer Science
International Business Machines Corp.
K51-282, Monterey and Cottle Roads
San Jose, CA 95193

Mr. Harry Reinstein
International Business Machines Corp.
1501 California Avenue
Palo Alto, Ca 94303

Illinois, University of

Mr. John D. Day
University of Illinois
Center for Advanced Computation
114 Advanced Computation Bldg.
Urbana, Illinois 61801

Institut de Recherches d'Informatique et d'Automatique (IRIA)
Reseau Cyclades
78150 Rocquencourt
France

Mr. Louis Pouzin
Mr. Hubert Zimmerman

Information Sciences Institute,
University of Southern California
4676 Admiralty Way
Marina Del Rey, CA 90291

Dr. Marty J. Cohen
Mr. Steven D. Crocker
Dr. Steve Kimbleton
Mr. Keith Uncapher

London, University College

Professor Peter Kirstein
UCL
Department of Statistics &
Computer Science
43 Gordon Square
London WC1H OPD, England

Massachusetts Institute of Technology

Dr. J. C. R. Licklider
MIT
Project MAC - PTD
545 Technology Square
Cambridge, Massachusetts 02139

MITRE Corporation

Mr. Michael A. Padlipsky
MITRE Corporation
1820 Dolly Madison Blvd.
Westgate Research Park
McLean, VA 22101

Network Analysis Corporation
Beechwood, Old Tappan Road
Glen Cove, New York 11542

Mr. Wushow Chou
Mr. Frank Howard

National Bureau of Standards

Mr. Robert P. Blanc
National Bureau of Standards
Institute for Computer Sciences
and Technology
Washington, D. C. 20234

Mr. Ira W. Cotton
National Bureau of Standards
Building 225, Room B216
Washington, D. C. 20234

National Physical Laboratory
Computer Science Division
Teddington, Middlesex, England

Mr. Derek Barber
Dr. Donald Davies
Mr. Roger Scantlebury
Mr. P. Wilkinson

National Security Agency
9800 Savage Road
Ft. Meade, MD 20755

Mr. Dan Edwards
Mr. Ray McFarland

Norwegian Defense Research Establishment
P. O. Box 25
2007 Kjeller, Norway

Mr. Yngvar G. Lundh
Mr. P. Spilling

Oslo, University of

Prof. Dag Belsnes
EDB-Sentret, University of Oslo
Postbox 1059
Blindern, Oslo 3, Norway

Rand Corporation
1700 Main Street
Santa Monica, CA 90406

Mr. S. Gaines
Mr. Carl Sunshine

Rennes, University of

M. Gerard LeLann
Reseau CYCLADES
U.E.R. d'Informatique
B. P. 25A
35031-Rennes-Cedex, France

Stanford Research Institute
333 Ravenswood Avenue
Menlo Park, CA 94025

Ms. E. J. Feinler
Augmentation Research Center

Dr. Jon Postel
Augmentation Research Center

Mr. D Nielson Director
Telecommunication Sciences Center

Dr. David Retz
Telecommunication Sciences Center

System Development Corporation

Dr. G. D. Cole
System Development Corporation
2500 Colorado Avenue
Santa Monica, CA 90406

Telenet Communications, Inc.
1666 K Street, NW
Washington, D. C. 20006

Dr. Holger Opderbeck
Dr. Lawrence G. Roberts
Dr. Barry Wessler

Transaction Technology Inc.

Dr. Robert Metcalfe
Director of Technical Planning
Transaction Technology Inc.
10880 Wilshire Blvd.
Los Angeles, CA 90024

Defense Communication Agency

Dr. Franklin Kuo
4819 Reservoir Drive
Washington, D. C. 20007

Xerox Palo Alto Research Center
3333 Coyote Hill Road
Palo Alto, CA 94304

Mr. David Boggs
Dr. William R. Sutherland

STANFORD UNIVERSITY

Digital Systems Laboratory

Mr. Ronald Crane
Mr. Yogen Dalal
Ms. Judith Estrin
Professor Michael Flynn
Mr. Richard Karp
Mr. James Mathis
Mr. Darryl Rubin
Mr. Wayne Warren

Digital Systems Laboratory Distribution

Computer Science Department - 1 copy
Computer Science Library - 2 copies
Digital Systems Laboratory Library - 6 copies
Engineering Library - 2 copies
IEEE Computer Society Repository - 1 copy

Electrical Engineering

Dr. John Linvill